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Necrophagous flies assemblages: Spatio-temporal patterns in a Neotropical urban environment

Ensamble de moscas necrófagas: Patrones espaciales y temporales en un ambiente urbano neotropical

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ABSTRACT
Species composition, richness, and relative abundance of the communities of Calliphoridae, Muscidae, and Fanniidae in Córdoba city, Argentina was assessed, and how these characteristics are affected by seasonal and anthropogenic conditions was studied. The study was carried out in thirteen sites with various levels of urbanization during 2014 and 2015, comparing two seasons: the warmer-wet summer and the cold-dry winter. Adult flies were collected in each site using two traps baited with hydrated bone meal. A total of 1683 flies were collected, belonging to twelve genera and 22 species. Several of the species collected are relevant to forensic sciences. The most frequent species were *Hydrotaea aenescens* (Muscidae) and *Fannia fusconotata* (Fanniidae). No differences in necrophagous fly richness or relative abundances between the central urban sites and the periphery suburban sites were observed; however, richness was significantly correlated with local (250 m buffer area) built-up density. Species composition differed between the urban and suburban sites. Seasonal differences were also detected: the relative abundances per species were more even in the summer. Dissimilarities in the assemblages were mainly due to differences in the relative abundances of some species, reflecting their adaptability to landscapes with different degree of urbanization. Regardless of season or urbanization density, species richness and effective number of species were higher in traps placed in the sun as opposed to shade. Taken together, these results suggest that in Córdoba city both landscape and local factors explain variations in the necrophagous fly community.

Key Words. Community, forensic entomology, necrophagous flies, urbanization.

RESUMEN
Se evaluó la composición, riqueza y abundancia relativa de especies de las comunidades de Calliphoridae, Muscidae y Fanniidae en la ciudad de Córdoba, Argentina, y se examinó cómo estas características son afectadas por las condiciones estacionales y antropogénicas. El estudio se llevó a cabo durante 2014 y 2015 en trece sitios con diferentes niveles de urbanización, comparando las estaciones de verano cálido-húmedo e invierno frío-seco. Se recolectaron moscas adultas en cada sitio utilizando dos trampas cebadas con harina de hueso hidratada. Se recogieron 1683 moscas, pertenecientes a doce géneros y 22 especies. Varias de las especies recolectadas son relevantes en las ciencias forenses. Las especies más frecuentes fueron *Hydrotaea aenescens* (Muscidae) y *Fannia fusconotata* (Fanniidae). No se observaron diferencias en la riqueza ni en las abundancias relativas entre los sitios urbanos centrales y los sitios suburbanos periféricos; sin embargo, la riqueza se correlacionó con la densidad de construcción local (250 m de área buffer).

La composición por especies difirió entre los sitios urbanos y suburbanos. Las abundancias relativas por especie fueron más uniformes en verano. Las disparidades en los ensambles se debieron principalmente a las diferencias en las abundancias relativas de algunas especies, lo que refleja su adaptabilidad a paisajes con diferente urbanización. Independientemente de la estación del año o de la densidad de urbanización, la riqueza de especies y el número efectivo de especies fueron mayores en las trampas al sol que a la sombra. Estos resultados sugieren que en la ciudad de Córdoba tanto el paisaje como los factores locales explican las variaciones en la comunidad de moscas necrófagas.

Palabras Clave. Comunidad, entomología forense, moscas necrófagas, urbanización.

INTRODUCTION

Decaying organic matter that becomes available within an ecosystem is a highly nutritious pulse resource for a wide variety of organisms. The most important taxa exploiting these resources are saprophagous (species that feed on decaying organic matter) and necrophagous (species that feed on decaying animal flesh, carrion) flies that colonize and use them to complete their development. Necrophagous flies are common inhabitants of urban ecosystems. The larval stages of some species of Calliphoridae, Muscidae, Fanniidae and Sarcophagidae families (Calyptratae) play an important role in the decomposition of organic matter, which in many cases is produced and accumulated by human activity in urbanization areas (Morales and Wolff 2010).

Calyptratae families have a strong flying ability that allows them a large dispersion, which enables them to reach a wide variety of environments. Some species of the Calliphoridae, Muscidae and Fanniidae families colonize carrion in successional waves depending on the degree of decomposition of the substrate and the biogeographic region (Battán-Horenstein *et al.* 2010). These characteristics confer importance to these species in forensic science, since they allow the precise estimation of the time of death. In addition, necrophagous flies may have medical interest as mechanical vectors of different biological pathogens (Cadavid-Sanchez *et al.* 2015), and some species may cause myiasis to vertebrates including humans (Greenberg 1973, Guimarães and Papavero 1999).

The spatial distribution of a species is the result of ecological interactions between the organisms and their environment (Hwang and Turner 2005). The most frequent species in urban environments are usually cosmopolitan or widely distributed, but there are also geographical variations (Patitucci *et al.* 2015). The fly pool available to colonize organic matter may vary between areas, establishing the diversity and richness of insect species–habitat associations. Species associations with different habitats and environments may be useful from a forensic perspective, for example to reveal whether a corpse was transported after death (Amendt *et al.* 2011). For example, *Lucilia sericata* (Meigen, 1826) and *Calliphora vicina* Robineau-Desvoidy, 1830 are Holarctic species that have become widely spread throughout the world (Greenberg 1973). Patitucci *et al.* (2011) defined both species as urban exploiters, consistent with the observations of other authors of these species being frequent in highly urbanized areas (Hwang and Turner 2005 in England, Patitucci *et al.* 2011, in Buenos Aires, Argentina, Kavazos and Wallman 2012 in Australia). In contrast, Battán-Horenstein *et al.* (2016) in Córdoba, Argentina, showed that both species were dominant in areas less urbanized, with intermediate housing density.

In Córdoba city, Argentina, Battán-Horenstein *et al*. (2016) compared the calliphorid assemblages in three urban areas differing in their construction density. They observed that species richness, diversity, and abundance were higher in areas with intermediate urbanization compared to high urbanization levels, suggesting that the intensity of urbanization affected the calliphorid community. However, in that study the sampling was restricted to the drier and colder months of the year, and coexisting species from other families were not taken in consideration. It is known that temperature and humidity have effects on species richness and abundance of individuals (Anderson 2001, Hwang and Turner 2005). Marked seasonality in the southern zone of the Neotropical region might have a direct influence on structuring communities of insects on decay organic matter because of the dissimilar preferences or tolerances of the species in the communities to climatic conditions. Data on seasonal variations in the fly assemblage are useful for forensic applications, as they may help to identify the season of the year when a death occurred (Amendt *et al*. 2011).Therefore, the aim of this study was to evaluate both the spatial and temporal variability of a wider range of necrophagous fly assemblages of the families Calliphoridae, Muscidae, and Fanniidae in terms of species composition and relative abundance, and to examine whether they are affected by seasonality, urbanization density and insolation conditions (sunlight and shade), in a temperate Neotropical city.

MATERIALS AND METHODS

Study area

The study was carried out in the city of Córdoba, which is situated in the center of Argentina (31° 25´ S, 64° 11´ W, elevation 440 m). The collections were carried out in 13 sites differing in their level of urbanization (Fig. 1). Site characterization was first based on photointerpretation of Quickbird (GoogleEarth) images combined with ground truth. Six sites, designated as urban, were in the densely built center of the city, with 85 % impervious surfaces (an average of 22 buildings per hectare). They were characterized by a predominance of

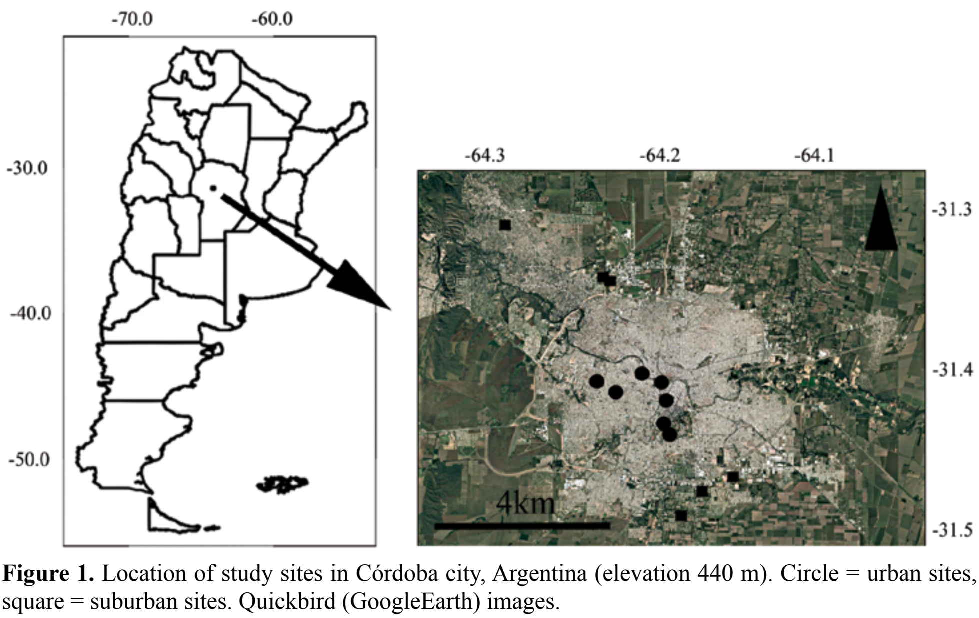

Figure 1. Location of study sites in Córdoba city, Argentina (elevation 440 m). Circle = urban sites, square = suburban sites. Quickbird (GoogleEarth) images.

commercial buildings, premises with < 50 m^2 backyards and small or no front yards, and parking areas, approximately 1 ha. Seven sites were located in suburban and peripheric areas of the city; these were designated as suburban. Four of these sites, on the west of the city, had a lower construction density of eight houses per hectare, 45 % impervious surfaces. Premises typically had larger gardens, and there were more trees but fewer recreational areas compared to urban areas. Large areas are used for agriculture, plant nurseries, and industrial activities, while other commercial activities are limited. Housing in the remaining three suburban sites on the east-southeast of the city were more isolated with four houses per hectare, 15 % impervious surfaces, and in close proximity to agriculture/horticultural, pig, and poultry farms.

Sites were further characterized by the percentage of built (impervious) surface within a 250 m buffer area around each site. Satellite imagery of Landsat 8 OLI (Operational Land Imager) L1T standard were acquired free of charge through the website of the US Geological Survey (http://earthexplorer.usgs.gov). Cloud-free scene 229/82 (September 13, 2015) with a spatial resolution of 30 meters was used; the bands of each scene are in digital integer number (DN) format with a radiometric resolution of 16 bits. These are converted to top of the Atmosphere (TOA) reflectance with scale factors provided in the metadata of the product (Landsat 8 Data User's Handbook, 2016). The area was delimited and an unsupervised classification was carried out using the K mean algorithm, using the normalized differences vegetation index (NDVI) (Tucker 1979) and normalized differences built-up index (NDBI) (Zha *et al* 2003). Built/impervious and non-impervious coverage were discriminated. From each field georeferenced point, or site, a buffer of 250 m radius was made, where the percentage of impervious cover (built surface from now on) corresponding to the classification was extracted.

Sampling procedure

The study was carried out during 2014 and 2015. Each year a summer (warm-wet) and a winter (cold-dry) period were selected to collect flies. The mean temperatures in summer (from mid-December to mid-March) and winter (from mid-June to mid-September) of the two sampling years were 21.47 °C, 12.16 °C (2014) and 22.03 °C, 12.71 °C (2015), respectively. Adult flies were collected in each site using two traps hang by a cord from a tree branch, one in the sunlight and one in the shade, baited with 200 grams of bone meal (putrescine), which is a foul-smelling organic chemical compound produced by the breakdown of aminoacids in living and dead organisms (Olea *et al.* 2017). Traps were adapted from Hwang and Turner (2005) and described in further detail in Battán-Horenstein *et al.* (2016). They consisted of two plastic bottles (500 ml and 1000 ml), one pushed inside the other forming two chambers, an upper collection chamber and a lower bait chamber. Holes allowed flies to enter the upper collection chamber through the bait chamber while restricting their escape. Within each site, traps were set 20 m to 40 m apart. Each season, the traps were installed for five consecutive days on each of three consecutive months; in winter, traps were active for ten days due to lower fly activity (following Hwang and Turner 2005), in order to ensure a more complete richness representation. Within each season, flies collected were pooled by site and insolation condition and considered a sample.

Taxonomic identifications were performed under a stereomicroscope to species level (Carl Zeiss Stemi 2000-C) using specialized keys based on the external morphological characters of specimens (Carvalho 2002, Whitworth 2005, Domínguez 2007).

Data analysis

Species data collected from a site along the sampling period were pooled to estimate overall species richness and verify the completeness of the necrophagous fauna inventory. We assessed the sample coverage (C), which is the fraction of incidence probabilities associated with the detected species using the software Spade (Chao *et al.* 2005) and Infostat (Di Rienzo *et al.* 2014).

For each site, insolation condition, and sampling season, the observed species richness and effective number of species (diversity of order 1, or Shannon diversity (exp(H)) were estimated. Differences in total fly species richness or effective number of species between urban and suburban sites, summer and winter seasons, and sunlight or shade insolation were assessed using general linear mixed models. The response variables were richness or Shannon diversity. Fixed effects were site type, season and insolation; random effects were sites and sampling year (2014, 2015). The threshold for assessing significant differences was set at $p < 0.05$ (Infostat; Di Rienzo *et al.* 2014).

The percentage of built surface were compared between urban and suburban sites with ANOVA. Relations between built surface and richness or effective number of species were assessed with Spearman´s correlation.

Variation in community composition amongst seasons, sampling sites and insolation conditions, using relative abundance and ln (n+1) transformed data, were tested with non-parametric multivariate analysis of variance (PERMANOVA) based on Bray-Curtis distances with 10 000 permutations (Hammer *et al.* 2001). Similarity percentages (SIMPER) were calculated where these groups differed to determine which species made the largest contribution to the dissimilarities (Clarke and Warwick 2001) Analyses were conducted with the package Infostat (Di Rienzo *et al.* 2014).

RESULTS

Calliphoridae, Muscidae and Fanniidae families totalized 1683 specimens, belonging to twelve genera and at least 22 species (158 specimens could only be identified as morphospecies 1 or 2) (Table 1). The most abundant species collected were *Hydrotaea aenescens* (Wiedemann, 1830) and *Fannia fusconotata* (Rondani, 1868). Both species were also the most widespread, found in all sampled seasons and locations. Species coverage for each site was always higher than 70 %, indicating an acceptable representation of the necrophagous fauna that may be collected with the baited traps.

There was a significant effect of insolation condition ($P = 0.01$), but not of season ($P = 0.09$) nor location ($P = 0.47$) (Figs. 2a-c) on species richness. Richness was higher in traps located in the sun compared to shade regardless of season or location in the center or city periphery (Fig. 2c). The effective number of species was significantly higher under sunlight condition ($P = 0.003$) and in the summer ($P = 0.008$) but there were no significant effects of location ($P = 0.54$) (Figs. 3a-c).

As expected, the percentage of impervious surface was significantly higher in the urban (85.5 ± 9.1, mean ± standard error) compared to the suburban (53.6 ± 8.6) sites. Species richness was significantly and negatively correlated with the percentage of built surface ($r_s = -0.75$, $P = 0.003$) (Fig. 4).

The PERMANOVA showed that species composition significantly differed between locations ($F = 3.32$, $P = 0.002$) and seasons ($F = 3.80$, $P = 0.0002$). Regarding seasonality, *H. aenescens*, *F. fusconotata*,

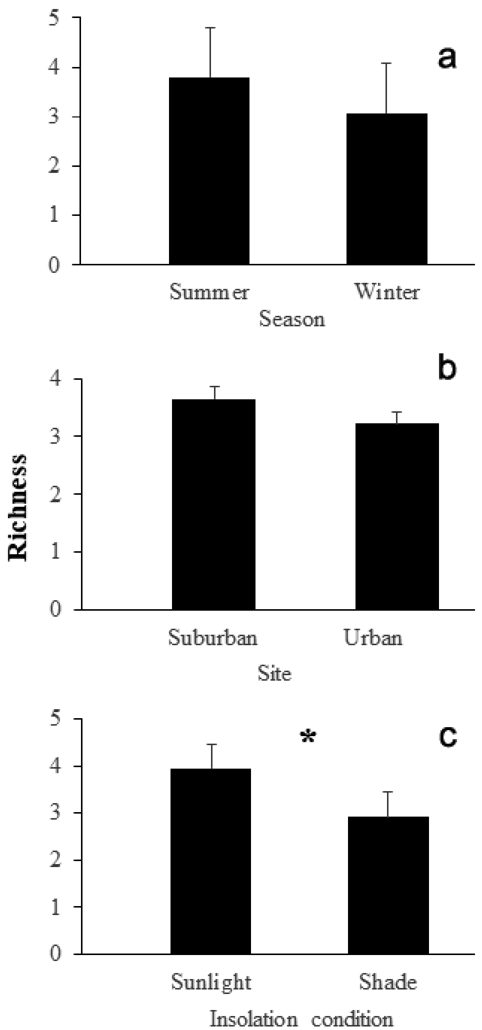

Figure 2. Species richness (mean+ s. e.) per **a**. Sampling season; **b**. Study sites; **c**. Insolation condition. * indicates significant differences (*P* = 0.05, n = 104).

M. stabulans (Fallén, 1817), A. *reversura* Villeneuve, 1936, and *C. vicina* more contributed to the dissimilarity, being *H. aenescens* and *M. stabulans* more frequent in the winter. *Calliphora vicina* was only collected in the winter, while other rare species such as *F. albitarsis* Stein, 1911, *L. ochricornis* (Wiedemann, 1830) and *L. cuprina* (Wiedemann, 1830) were only found in the summer (Table 2). *Hydrotaea aenescens*, *M. stabulans*, and A. *reversura* were more abundant in the suburban sites while *F. fusconotata* was mainly found in urban sites (Table 3). Insolation condition had an overall significant effect on species composition and relative abundances (F = 1.972, *P* = 0.04).

DISCUSSION

Fanniidae was the most abundant family in this study. This family is cosmopolitan, but most species are found in the Holartic region, with few records in the Neotropics. All Fanniidae collected in this study belong to the genus *Fannia*. According to several authors, *Fannia* is a common component of the saprophagous community, which also accounts for its association with humans (Anderson and Van Laernhoven 1996, Tantawi *et al*. 1996, Rozkosny *et al*. 1997). Both *F. fusconotata* and *F. scalaris*, the most abundant species of Fanniidae collected, are believed to cause different types of myiasis in humans and in cattle (Oliva 1997).

Muscina stabulans, *H. aenescence*, and *A. reversura* were the three most abundant species of the family Muscidae. *Muscina stabulans* is a cosmopolitan species, very common in the Neotropics (Carvalho and Couri 2002). Linhares (1981) suggested that *M. stabulans* is a eusynanthropic species always found near human environments, particularly in rustic, primitive rural neighborhoods, but is scarce in towns. Our results agree with this, since *M. stabulans* was more abundant in the suburban sites. Patitucci *et al*. (2010a) in a more humid area of Buenos Aires observed that this species is mostly associated to the urban-suburban sites than to rural ones. The association of *M. stabulans* with different degrees of urbanization shows that this species can adapt to and exploit disturbed environments.

Table 1. Species composition and number of flies collected each season (pooling both sampling periods per season) and insolation condition in Córdoba city, Argentina.

Family	Genus/species	Season	Warm		Cold		
		Insolation	Sunlight	Shade	Sunlight	Shade	Total
Muscidae	*Hydrotaea aenescens* (Wiedemann, 1830)		39	109	90	185	523
	Atherigona reversura Villeneuve, 1936		35	30	46	25	136
	Muscina stabulans (Fallen, 1817)		20	19	38	37	114
	Muscina domestica Linneo, 1758		24	8	1	-	33
	Synthesiomyia nudiseta (Wulp, 1883)		17	10	3	1	31
	Psilochaeta chlorogaster (Wiedemann, 1830)		-	-	8	3	11
Calliphoridae	*Chrysomya albiceps* (Wiedemann, 1819)		-	-	3	17	20
	Lucilia exima (Robineau-Desvoidy, 1819)		5	7	-	8	20
	Lucilia sericata (Meigen, 1826)		8	1	7	2	18
	Chrysomya megacephala (Fabricius, 1794)		13	3	2	-	18
	Calliphora vicina Robineau-Desvoidy, 1830		-	-	8	7	15
	Sarconesia chlorogaster (Wiedemann, 1830)		6	-	-	-	6
	Lucilia ochricornis (Wiedemann, 1830)		2	-	-	-	2
	Cochliomyia macellaria (Fabricius, 1775)		1	-	-	-	1
	Lucilia cuprina (Wiedemann, 1826)		1	-	-	-	1
	Lucilia cluvia (Walker, 1849)		1	3	1	-	5
Fanniidae	*Fannia fusconotata* (Rondani, 1868)		106	71	74	148	399
	Fannia scalaris (Fabricius, 1794)		25	61	53	16	155
	Morphospecies 1		20	4	7	114	145
	Morphospecies 2		1	-	12	-	13
	Fannia albitarsis Stein, 1911		8	2	-	-	10
	Fannia canicularis (Linneo, 1761)		2	2	3	-	7

Hydrotaea aenescens is a widespread species from the Neotropical Region (Hogsette and Washington 1995). It is considered a synanthropic species, common in highly urbanized habitats (Patitucci *et al.* 2010b), however in this study it was more abundant in the suburban sites. It is interesting that the second most frequent species, *Atherigona reversura*, was only recently reported in Argentina, in Buenos Aires, Santa Fe and Chaco provinces (Patitucci *et al.* 2016). This species, commonly known as shoot-fly,

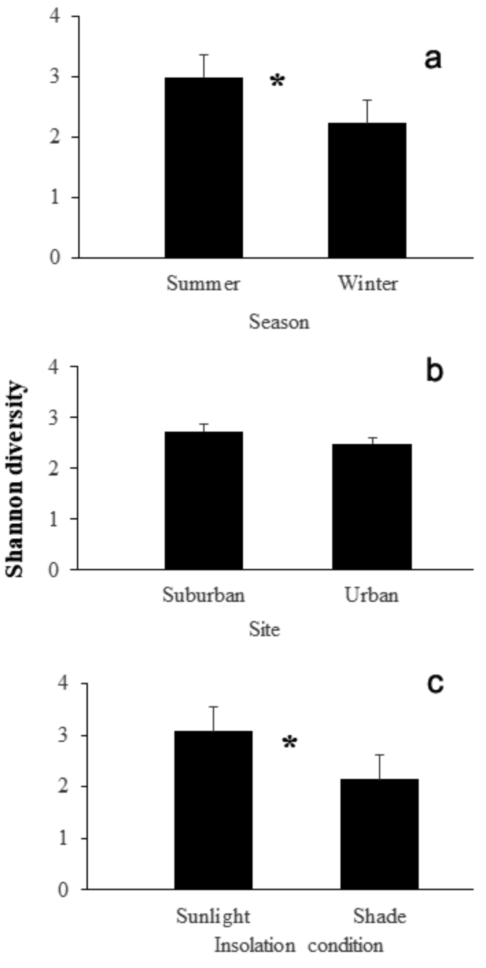

Figure 3. Shannon species diversity index (adjusted mean + s.e.) per **a**. Sampling season; **b**. Study sites; **c**. Insolation condition. * indicates significant differences ($P = 0.05$, n = 104).

being a pest of cereal crops, is originally from the tropics and subtropics of the Old World. It is linked to cultivated fields and uses mainly Bermudagrass (*Cynodon dactylon* [L.]) pastures and other Poaceae as host plants to breed (Patitucci *et al.* 2016). Their attraction to the hydrated bone meal bait suggests a broader resource preference.

Calliphorid species were represented mainly by *Lucilia* spp, *Calliphora vicina* and *Sarconesia chlorogaster* Wiedemann, 1830 and in low numbers by Chrysomya megacephala (Fabricius, 1794) and *Chrysomya albiceps* (Wiedemann, 1819). In this study and in concordance with previous observations by Battán-Horenstein *et al.* (2016), *L. sericata* and *C. vicina* were collected in urban and suburban sites. Both species of *Chrysomya* (*C. albiceps* and *C. megacephala*) have been introduced to the Americas in the mid-1970s (Guimarães *et al.* 1978, Baumgartner and Greenberg 1984) and quickly spread through Peru, Bolivia, Paraguay, Colombia, and Argentina (Mariluis 1983, Peris 1986).

The introduction of *Chrysomya* species has been reported to influence the native fauna, by displacing native species as *Cochliomyia macellaria* (Fabricius, 1775), producing a strong impact on the structure of local communities (Faria *et al.* 1999, Battán-Horenstein *et al.* 2007). *Cochliomyia macellaria* and *C. albiceps* have been classified as hemisynantropic (Linhares 1981, Ferreira and Barbola 1998), but in Córdoba they occur in urban areas (this work and Battán-Horenstein *et al.* 2016). However, these species were collected in very low numbers, in contrast to a study in the same city using pig carcass as bait (Battán-Horenstein *et al.* 2007, 2010). Differences in numbers collected may in part reflect a preference for larger carrion as opposed to a reduction in their populations, a possibility that merits to be further explored considering the invasive status of *Chrysomya*. More importantly, the type of bait used in this study to collect adult flies could have been the reason of the small number of individuals of this family. Calliphoridae species are primary colonizers of corpses (Centeno *et al.* 2002, Battán-Horenstein *et al.* 2007, 2010, Aballay *et al.* 2012) and attracted by the tissue liquids produced by degradation of lipids mainly, compounds that in bone meal are diminished. Fanniidae and Muscidae appear

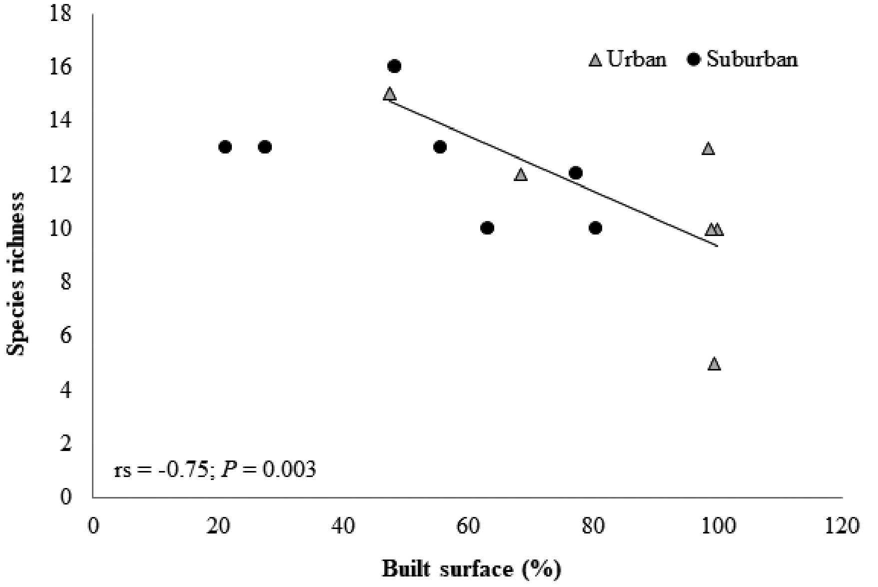

Figure 4. Spearman´s correlation between built surface and richness species.

associated with intermediate and final stages of decomposition (see Muscidae in Centeno *et al*. 2002, Fanniidae in Aballay *et al*. 2012, Sarcophagidae in Battán-Horenstein *et al*. 2010, Aballay *et al*. 2012), recording their maximum abundance when bones and associated organic compounds become available; this is likely to be the cause of the largest capture of Fannidae and Muscidae over Calliphoridae in this study.

Seasonal effects were observed on species collected. There was a higher effective number of species in the summer compared to winter samples. Many species of *Calliphora* appear to be more cold-adapted than other calliphorids (Faucherre *et al*. 1999). In this study, in particular *Calliphora vicina*, was only collected in the winter, coexisting with *S. chlorogaster. Calliphora vicina* has a distribution limited to areas where the summer temperatures do not exceded 30°C for sustained periods. In Córdoba *C. vicina* has been observed colonizing decomposing pigs mainly during cold periods of the year, and its populations decrease towards spring and summer (Battán-Horenstein *et al*. 2007). *Hydrotaea aenescens*, *M. stabulans*, and *A. reversura* were most abundant in the winter while *F. fusconotata* and *M. domestica Linnaeus*, 1758 were detected in higher numbers in the summer.

Muscina stabulans occurred in all samples during both years and in the urban and suburban sites. The higher abundance of this species was observed in the cold dry season. Patitucci *et al*. (2010a) analyzed different attributes of *M. stabulans*, like sex ratio, synanthropy, seasonal and daily numerical changes, bait preference, and heliophily, comparing them along an urban-rural gradient during two years in Buenos Aires, Argentina. In that work, *M. stabulans* was detected year-round, but in contrast to our findings, specimens were most abundant in the summer and spring. The *Lucilia* species are thermophilic (Hwang and Turner 2005) and consistently in this study were present in the warmer periods. However, *L. sericata* and *L. eximia* (Wiedemann, 1819) were also collected in cold periods. These results

Table 2. Contribution of each species to the observed dissimilarities between summer and winter assemblages (SIMPER analysis) in Córdoba city, Argentina.

			Winter	Summer
Taxon	**Contribution**	**Cumulative %**	**Mean abundance**	
H. aenescens	15.50	19.51	1.27	0.81
F. fusconotata	13.11	36.01	0.83	0.97
M. stabulans	8.42	46.61	0.75	0.48
A. reversura	7.58	56.16	0.44	0.42
F. scalaris	6.82	64.75	0.29	0.54
M. domestica	3.80	69.53	0.02	0.36
S. nudiseta	3.57	74.03	0.06	0.32
Morphospecies 1	3.44	78.36	0.38	0.11
C. megacephala	2.95	82.07	0.03	0.22
C. vicina	2.78	85.57	0.17	_
S. chlorogaster	1.91	87.97	0.16	0.06
L. sericata	1.54	89.91	0.08	0.12
L. eximia	1.49	91.79	0.05	0.13
P. chlorogaster	1.31	93.44	0.13	0.00
Morphospecies 2	1.12	94.85	0.07	0.02
C. albiceps	1.11	96.24	0.00	0.10
L. cluvia	0.85	97.31	0.02	0.06
F. canicularis	0.84	98.36	0.03	0.06
F. albitarsis	0.72	99.27	_	0.10
L. ochricornis	0.24	99.57	_	0.03
L. cuprina	0.22	99.84	_	0.02
C. chlorogaster	0.13	100.00	_	0.02

could be a consequence of adult survival during the winter.

Other local factors such as insolation may influence the fly fauna attracted to the potential food resource. In Córdoba, the average summer effective heliophany (the number of hours with sunshine for a given day and place) is higher than in winter (7.66 h compared to 5.3 h, Grossi Gallegos and Righini 2007). However, the effective number of species in traps exposed to sunlight was higher than in traps placed in the shade regardless of season, suggesting that responses to these factors were independent.

Table 3. Contribution of each species to the observed dissimilarities between urban and suburban assemblages in Córdoba city, Argentina.

Taxon	Contribution	Cumulative %	Suburban	Urban
			Mean abundance	
H. aenescens	15.39	19.39	1.33	0.62
F. fusconotata	13.77	36.74	0.75	1.13
M. stabulans	8.37	47.28	0.67	0.55
A. reversura	7.43	56.64	0.51	0.32
F. scalaris	6.71	65.09	0.51	0.24
Morphospecies 1	3.50	69.50	0.23	0.29
S. nudiseta	3.37	73.75	0.21	0.13
M. domestica	3.37	77.99	0.24	0.09
C. vicina	2.92	81.66	0.04	0.17
C. megacephala	2.89	85.31	0.09	0.16
S. chlorogaster	1.86	87.65	0.14	0.07
L. sericata	1.63	89.71	0.08	0.12
L. eximia	1.57	91.68	0.05	0.15
Morphospecies 2	1.42	93.47	_	0.11
P. chlorogaster	1.17	94.95	0.11	_
C. albiceps	1.15	96.40	0.03	0.08
F. canicularis	0.89	97.52	0.03	0.06
L. cluvia	0.79	98.51	0.05	0.02
F. albitarsis	0.65	99.33	0.06	0.03
L. ochricornis	0.19	99.58	0.02	_
L. cuprina	0.19	99.81	0.01	_
C. chlorogaster	0.15	100.00	_	0.02

This may be interpreted as that summer-winter variations are related with seasonal dynamics of the species, while sun-shade contrasts are more related with the selection of local habitat characteristics. It is known that *C. vicina* has a strong negative heliophily and *L. sericata* positive heliophily, however in this study both species were collected in similar numbers both in the sun and shade conditions (Table 1). These results could indicate that the levels of shade and sun considered were not enough to prevent the arrival of these species.

Results did not show differences in necrophagous fly assemblages in terms of richness or relative abundance between the urban and the suburban sites. However, urbanization intensity (=built surface) at a more local scale (250 m buffer area) negatively affected species richness. We may speculate that resources for the fly immature to develop may be more abundant or likely in areas with more green cover by the presence of dead animals, urban waste that remains more in time.

There were also effects of sun exposure of the traps on the diversity of species collected, being collections from sunlight traps richer. Variations in species composition detected between seasons and locations were mostly due to differences in the relative abundances of species and not so much to species segregation. The low spatial differences may be explained by the habitats studied not being different at the landscape scale considered (center vs periphery) as such for the fly community. The effects of other landscape or local factors such as land use and waste availability, as well as other substrates used to attract the flies should be considered in future studies to assess whether they better explain fly assemblages in the urban environment.

This kind of studies are relevant to generate basic information about the distribution and dynamics of necrophagous species that are used to estimate time of death, movement of a corpse and other related conditions useful in forensic research. The fact that many species of Calliphoridae colonize dead bodies in the early stages of decomposition makes them important forensic indicators (Anderson and Van laerhoven 1996). Species of Muscidae and Fanniidae have also been widely cited in relation to decaying bodies in legal investigations (Smith 1986). *Fannia fusconotata*, *F. canicularis* (Linnaeus, 1761) and *F. scalaris* (Fabricius, 1794) (Fanniidae) are believed to cause different types of myiasis in humans and in cattle and are considered important in forensic investigations. *Muscina stabulans*, *M. domestica*, and *O. aenescens* (Muscidae), have been found associated with pig carcasses and in entomological forensic investigations (Battán-Horenstein *et al*. 2010).

AUTHOR’S CONTRIBUTIONS

BHM and GRM design of the experiments, data collection and analysis and manuscript writing.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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